USING BIOGAS TECHNOLOGY TO SOLVE PIT LATRINE WASTE DISPOSAL PROBELMS

Introduction

This technical brief looks at the option of using biogas units to reduce the waste produced by standard pit latrines. Waste is removed from the pit and transported to a biogas system where treatment takes place.

As populations grow and urban migration places further strain on towns, problems surrounding the applicability of on-site sanitation facilities such as *pit latrines* (Figure 1*)* and how they were originally supposed to operate are increasing.

Using a pit to retain the faeces underground for approximately two years making it less harmful requires space, which densely populated regions such as slum areas do not have, and there are cost implications of repeated construction.

Therefore users must empty their latrines and reuse them whenever possible. This has been the subject of much research over the past few years, but what is then done with the emptied waste has received little attention.

Figure 1: Pit latrines in the Kibera informal settlement (slum) in Nairobi, Kenya.
Photo: Karen Robinson / Practical Action.

The need to collect sludge from an on-site system, transport it to a treatment facility and dispose of it hygienically was given the term Faecal Sludge Management (FSM) by the Department of Water and Sanitation in Developing Countries (SANDEC) in Switzerland. Figure 2 shows that the first step to solving disposal issues is to implement a structured procedure that defines how waste should be managed. Without it pollution of the environment will occur earlier (i.e. during a transportation stage).

Biogas technologies

Biogas is the by-product of anaerobic digestion, the breaking down of organic material in the absence of air. The gas is rich in methane and can be used as a fuel for cooking, lighting and generating electricity. Anaerobic digestion takes place in what is known as a digester. Traditionally digesters have been directly linked to the latrine so the fresh faeces are subjected to digestion immediately. Little work has been done to see if using mature, partially digested waste from a pit latrine is feasible in producing biogas.

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technical brief

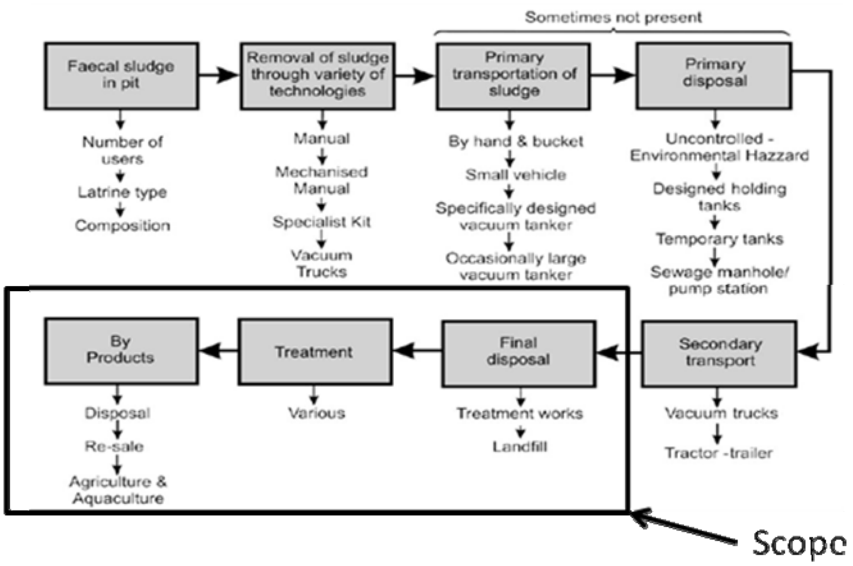

Figure 2: Faecal Sludge Management Cycle - (Boot N. , 2007)

Possible Digester options

The aim of the digester is to provide a sealed vessel that allows input of feedstock and removal of gas whilst being built of locally available construction materials.

The options of digester design are described in the Practical Action Technical brief Biogas The most common types of digester are the floating dome or Indian digester and the fixed dome or Chinese digester.

Other digesters include the *bag* or *balloon* digester, a type of Plastic Bio-Digester and the *plug flow* digester which is a type of Earth-pit plant. Both of these are more suitable in emergencies or situations where a digester is needed quickly or only for a short period of time because of their small life span in comparison to the above.

Assessing the technology

Technological barriers

The issues regarding technology can be split into *collection, haulage, disposal* and *treatment.*

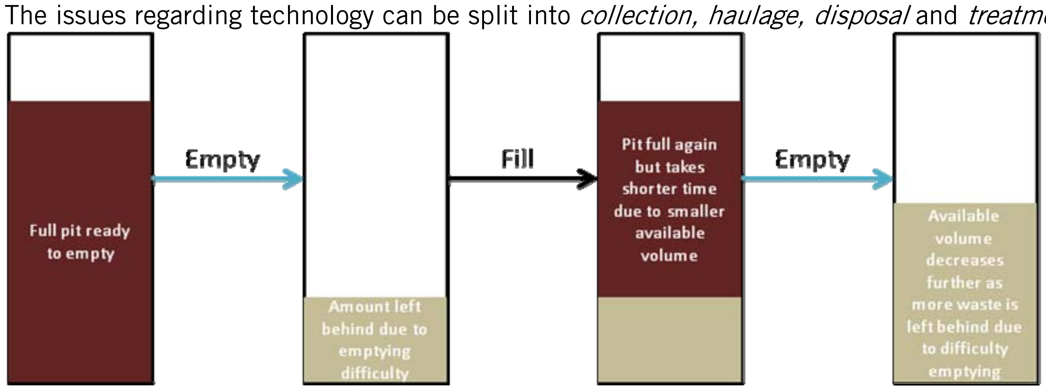

Figure 3: A diagram explaining the problem of soiling up

Collection: the sludge will be partially degraded upon emptying therefore decreasing the maximum methane yield. This means, to make the system feasible the frequency of pit emptying will have to increase. Pit emptying frequency is inversely proportional to the operational life of the pit. Dismantling often required when emptying a pit. A solution proposed is to fit an in-situ pipe to the pit that has an exit outside the super structure (Figure 4). This addition will limit the disruption caused by emptying as well as making the whole process more hygienic because the hose will no longer have to be dropped into the faeces. The addition will also help deal with the problems regarding viscosity and *soiling up* in pits (3) because emptying will happen from the bottom and water can be added through the pipe to decrease the viscosity.

Haulage: for sustainability reasons and to limit costs the push is to combine the system with manually operated emptying technologies (Boot N., 2006). These technologies are also more feasible in urban settings where access is an issue for vacuum pumps. When using these technologies it is not the distance from the latrine to the disposal point that is the defining factor but the time it takes. In this situation a *cost/time benefit calculation* should be used working backwards from the costs that must be covered for the system to work which will give the number of empties per day required. Using this information and the average working day a suitable haulage distance can be calculated.

Disposal: essentially the placement of the digester which is governed by three main factors:

- Space and land tenure; in slum areas space is sparse and they live on land they do not own so improving sanitation facilities is not high on their priority list
- Not in my back yard (NIMBY); people do not want waste dumped where they live however this is a very context specific area
- Use of the gas; whether it be a communal facility or private household

Logistic issues also affect the placement as outlined above.

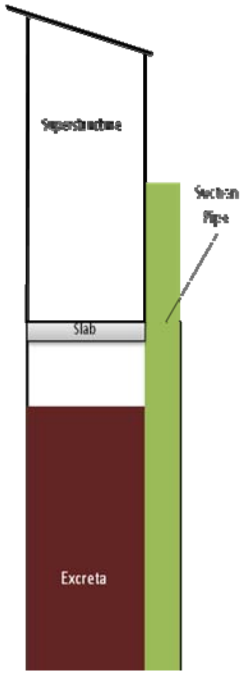

Figure 4: A diagram conveying the use of an in situ pipe.

Treatment: there are essentially two main issues regarding treatment. The first is problems surrounding pressure of the gas. One solution would be to ensure that the digester is correctly maintained. Another physical solution, highlighted by Kossmann (1999), is the use of a separate gas holder. Floating drum digesters allow the user to alter the pressure of the gas by applying weight and pushing the moving *"drum"* down. Research has highlighted maintenance issues surrounding these digesters and that fixed dome digesters provide better results. Therefore a possible solution is to take the benefits from both technologies and use them to their full advantage by using the fixed dome design for the batched digester setup while connecting a floating drum design in series to act as storage, so when/if the user does experience pressure complications they can apply an amount of weight to the top of the drum and increase the pressure.

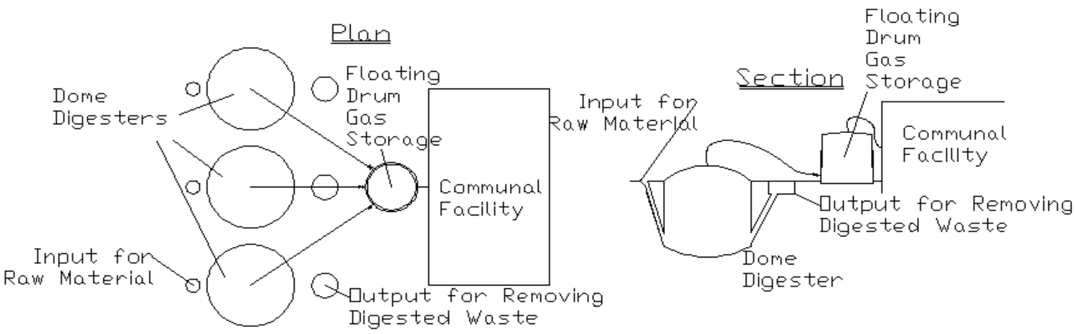

Figure 5: Possible digester setup to deal with pressure issues.

The other treatment issue that needs to be assessed is the concentration of nitrogen in the feedstock. Mang & Li (2009) describes how urea from urine will be toxic to the bacteria (self-intoxification) involved in digestion. In practice, Mang & Li(2009) stress it is important to maintain, by weight, a Carbon/Nitrogen (C/N) ratio between 20-30:1. The C/N ratio can be manipulated by combining materials low in carbon with those that are high in nitrogen, and vice versa (The United Nations, 1979). "*If the C/N ratio is very high the biogas production will be low; if the C/N ratio is very low, the pH value will increase, and will have a toxic effect on bacteria"* (Mang & Li, 2009).

Social and cultural issues

The first area of concern regarding social and cultural issues is tackling problems regarding the community's willingness to use the technology. There are three main areas that must be dealt with to ensure a successful implementation.

First the implementer must keep the public well informed. It is "*extremely difficult to achieve change in excreta disposal practices as they are part of the basic behavioural pattern of a community and are not readily modified*" (Faechem & Cairncross, 1978). Chaggu et al (2002) identify in Dar-es-Salaam that there is a lack of understanding why the disposal system has to be changed because of the "*lack of perceived benefits*" (IRCWD, 1982) biogas technology has. The low education level results in "*inadequate financial resources*" (Chaggu et al, 2002) so the priority is not a good excreta disposal when there is competition for financial resources. This poor education level leads a low level of involvement (Strauss et al 2002) and without involvement, construction and maintenance skills cannot be passed on.

This lack of knowledge can lead to an unwillingness to use the by-products, (Strauss & Montangero, 2002) the second area of concern. When assessing the willingness to use the residual as a soil conditioner the critical factor is land to use the conditioner on. If people do not have gardens or areas to use compost, like in urban areas, then they are not going to want it. One solution suggested is for farmers and other industries that have use for soil conditioner to collect the treated sludge. This will be dependent on a number of factors including sufficient access for the farmer's haulage vehicle to collect the soil conditioner, the collection being more beneficial for the farmers (i.e. quicker and cheaper) than collecting from their normal supplier and also the dependability of the agreement. Gas should be more acceptable than the residual because of the lack of direct contact with consumables that soil conditioner has. However the reasons why people do not like the use of digestion by-products cannot always be attributed to a straight forward misunderstanding. Often these decisions are difficult to understand.

The final concern when dealing with willingness to use the technology is religious issues over human excreta. Night soil workers carry a stigma, Eales (2005) explains that in Kibera residents see the job as illegal and it is therefore "*legitimate to assault those who haul stinking buckets and drums through narrow alleys".* This leads to emptying taking place at night because there is less chance they will be robbed or beaten. The idea is to make the process as less obtrusive as possible, which implementing manually operated systems will do. This will limit the disruption to the customer and therefore their opinion of emptying will improve. Regarding cultural taboos research could only come back to the use of education programmes put in place to help people understand the benefits of the practice, but once again this factor is very context specific.

Another area of concern is the effect of increasing the emptying frequency. There are two ways the user can be affected, the increase in frequency of payments and, the inconvenience to the occupant. The inconvenience to the user can be limited through improved emptying practices as outlined throughout this brief. Regarding the former point, currently, the occupant will relate the pit being full to emptying time. The challenge the implementer faces is to remove that link and in its place put in an ideology that instead of waiting for the pit to fill, have it emptied on a more regular basis so the user has more control over payments. The burden households face when saving up for one large payment is often too much and can often leave them in financial disarray. A smaller more frequent payment will be easier to manage removing the cash flow risk large payments carry. It is important that these smaller more frequent payments do not leave users worse off financially. If you can incentivise the setup by decreasing the emptying costs because the implementer is benefiting from the by-products generated from the sludge, then the technology is more likely to get unified backing. This theory of incentivising can also be applied to the emptier, making it beneficial for them to dispose of the waste in the correct area by paying them per load. In this situation care must be taken that loads are not bulked up with water from a surface water source in order get more empties per day.

The final point regarding social and cultural issues is the importance of educational programmes. Firstly, as with so many social factors, educational programmes are context specific based on culture and current practices and therefore the implementer should deal with issues on a case by case nature. The second point is the need for education in improving community awareness. This is important for preventing situations where technologies are refused due to radical changes in sanitation practices. Thirdly, the public need confidence in the procedure to aid acceptance, so educational programs will be used to give training to the service providers to improve processes therefore improving the experience for the customer.

Regarding the organisation of these programmes the initial step, as with any new implementation is the organisation of a piloting scheme to see how effectively the process works. It is at this point acceptability of the process must be achieved, with one solution being incentivising decisions once again by making the fuel much cheaper than the alternatives, so the community use it and see the benefits. What a piloting scheme also helps to do is create a sense of *"keeping up with the Jones'"* so implementation in neighbouring communities is easier. After analysis, if a piloting scheme is successful and the funds are available to grow then the technology can be implemented on a larger scale. The first area of a good educational programme is promotion at home. This not only regulates practice but also helps to install a sense of ownership with the householder that not only helps with maintenance issues but also helps acceptability because people will feel in control of their own practices and not dictated to. Promotion at home will often require visits, usually conducted by *"hygiene teams"* whose job it is to outline any change in practice and promote it and address any issues the household has. As well as hygiene team visits, visual materials should be used around the community to keep the public informed, for example directions to solid waste disposal points. As well as hygiene and process education there is also construction education which will involve passing down skills to local workmen so the whole process becomes more sustainable. Figure 6 outlines where education will be needed and why. The dashed outline signifies those tasks carried out by a hygiene team and the solid outline the more technical education.

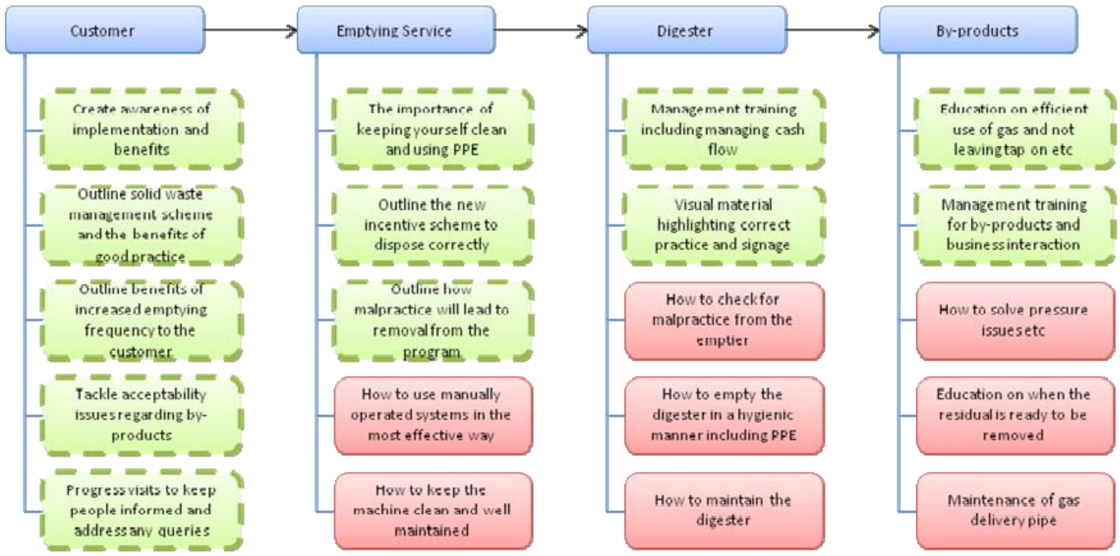

Figure 6: Need for education at each process stage

Organisational structure and management

On a basic level the implementation of a decentralised wastewater treatment system such as a biogas digester will only be successful if the necessary knowledge and skills to operate and maintain them are *"available at the local level"* (Parkinson & Tayler, 2003). It is therefore *"necessary to consider the development of an effective and needs responsive policy towards the issue of wastewater management"* (Hasan et al 2004). The Household Centred Environmental Sanitation (HCES) approach provides a framework for people centred decentralised wastewater management where the emphasis is not on waste as a burden but as a resource. Decisions about implementation start at household level, rising up through the community making sure that all users fully understand what is happening (Schertenleib & Morel, 2003). The approach is very much holistic. The idea is by making the system *"locally organized and people-driven"* (Heymans et al 2004) the community will pick up the necessary skills and knowledge to maintain and operate the technology without any outside supervision, providing a long lasting sustainable system. It is important to provide governmental policies that are enabling and not prescriptive. It is far better for the community to embrace the technology because they have been made aware of all the benefits than be told to embrace it from a higher level of government. Many wastewater systems stop working due to neglect and this kind of implementation will only lead to this situation.

Organisational structure is a context specific area of work for any technology implementation. Therefore systems must be put in place to understand what best works for that particular community and how can you get all the stakeholders collaborating in the most effective way. The issue currently with organisational structure highlighted through research is that it forms an unclosed loop, a situation which will never be sustainable. There are too many areas where the process can break down due to corruption or cost cutting, which is a big problem at survival level.

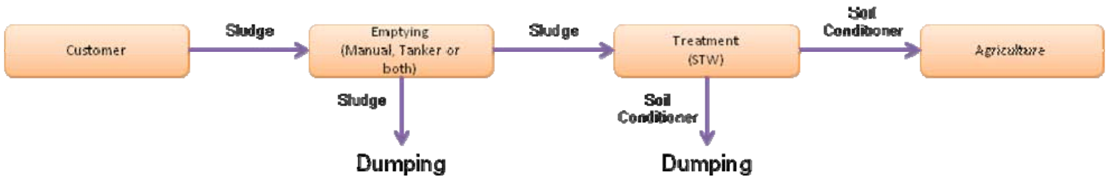

Figure 7: Typical Faecal Sludge Management Process

Flow of material making waste a resource
Current practices perceive waste as a burden. Therefore FSM often becomes a process, not a cycle, where the material is moved from body to body. People want to remove the burden as quickly as possible resulting in inappropriate dumping. Changing opinion of waste, will make stakeholders want to hang on to and re-use it to benefit from its resources. This will make management of faeces cyclical and therefore more sustainable bringing benefits back to the stakeholder.

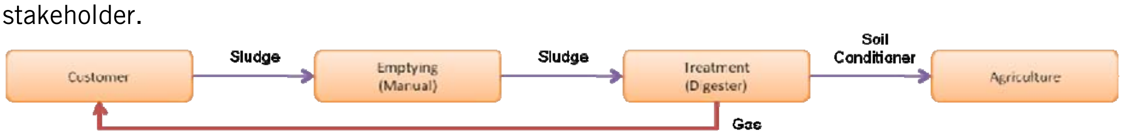

Figure 8: Faecal Sludge Management with waste as a resource

This brings benefits to the organisational structure that can be financial as well as environmental. People will only conform to this improved FSM if a degree of personal benefit is conveyed. Therefore a reform of how the finances flow around the organisational structure is needed to incentivise behaviour.

Flow of finances
Much like the problems seen in the flow of material, money flows through the process leaving interactions weak and susceptible to corruption. The money flows from left to right constantly draining out of the programme leaving the loop open. A theory generated through research is incentivising behaviour using money. Figure 9 conveys a suitable model.
Firstly it reverses the flow of money, incentivising the emptying contractors to perform their

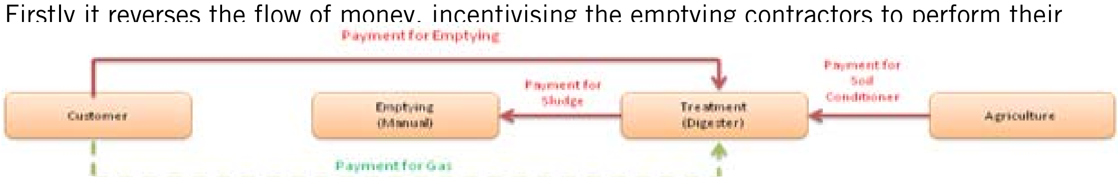

Figure 9: Financial model by-passing the customer/emptier transaction

task decreasing dumping, and also solving the issue of where to spread the residual by forging agreements with local farmers as outlined above. Instead of the emptier receiving their money from the customer, they would get paid on delivery of the sludge to the digester. This would ensure collection and correct delivery, closing the loop. Also the dashed payment arrow conveys money flowing back into the model, making the whole setup more sustainable. Generation of revenue from gas will be based on its use, acceptance permitting. Research has identified that the transaction between customer and emptying contractor is weak and susceptible to corruption. This model by-passes the connection and flows the money around the problem.

Care must be taken to ensure good regulation when using this model because the digester stage of the process becomes critical. The initial issue highlighted from research about removing the exchange of funds between the customers and emptier is quality of service. If the emptier views that they are providing a *"free"* service to the customer, then they are less likely to perform. The idea would be to remove this perception and make it clear the customer is still paying for this service and therefore standards should be high or they will be removed from the programme.

Management and regulation
The most suitable model from research is one where each stakeholder is responsible for their task, but an overall organisation is employed to look over the whole process (Figure 12). Their job will be to help organise the material and cash transactions as well as helping to ensure guidelines are met.

Figure 10: Management structure showing each stakeholder is separate but has an overseeing organisation

Research suggests a possible collaboration with a local water company could help due to their managerial, technical experience and their understanding of the local community. They could also help organise the tariff structure to be used.

Using this management model removes the rigidity that legalised regulation carries and promotes *self-regulation.* Each stage in the process having its own management setup means someone will always be there to monitor what is being put into the digester and therefore the transaction with the emptier. The *janitor* can also manage the communal facilities ensuring they are well maintained and prevent misuse. The post will also be responsible for emptying the digester and liaising with the organisation that will be taking the residual away. There will be a close relationship between the janitor and the overseeing organisation to make sure the money does not stay too long on site to prevent theft. Competition is important for any sustainable model, therefore by making each stage self managed all emptying contractors, small or large will be able to participate as long as they conform to the program set out by the overseeing organisation.

The economic argument

Initial investment
The initial issue (Bates 2007) is the high set-up costs of a biogas system. There are labour and material costs associated with the digesters but also the construction of the gas delivery method. Parkinson et al (2003) indentifies that although decentralised systems do reduce the

cost of investment in comparison to large complex centralised treatment infrastructure, the majority of government agencies lack the funds to invest, so it is usual to look to the private sector (Bates, 2007), higher levels of government (Parkinson & Tayler, 2003), or overseas agencies (Myles, 2001) to help fund the project.

The issue with private backers is that very often they want a worthwhile return for their investment, which is notoriously hard in sanitation, placing added pressure on the programme. Community based organisations are often unreliable because it is hard to find a common ground for all people involved that they all feel strongly for due to the perceived unimportance of sanitation. A solution is to collaborate with a local water company, so the programme is funded by the government, but run in conjunction with the community. This way there will be less pressure to perform but there will be the management and technical backing to help the programme succeed.

Willingness to pay
For gas usage: It is easy to see that to create willingness requires incentive. In this case the incentive comes from the use of the gas; therefore it is imperative a use is picked that is suitable to the community in question. There are a number of different uses for the facility each with the positives and negatives. One idea is a communal kitchen type facility where people could come and do cooking when and if they needed it, if accepted socially. One possible issue with this is that some cultures may be averse to cooking communally/side-by-side therefore knowledge of local practice will be required before choosing a kitchen. Another issue would be the tariff structure and how the usage would be charged. One idea would be per unit time because gas flow measurement from biogas is notoriously difficult. However, charging per unit time can have an effect on the user because they will want to be in and out as quick as possible which may lead to chaotic conditions and poor public opinion. Another idea would be to package up the benefits so the user pays for the emptying and the use of the communal facility is an extra. This creates the perfect situation for waste because the user will not connect a direct cost with the gas, dropping the efficiency of the system. Another issue that must be considered when assessing willingness to pay is habit, and the fact that many communities will always cook certain foods using solid fuels. This means biogas will never fully replace solid fuels for cooking because traditions are hard to remove. Another solution is the market context, where the gas is used by a local business that pays a monthly fee for a connection. This is based on the community needing the facility.

For emptying: Increasing the emptying frequency has been addressed but people's willingness to pay for this will further be improved by the natural risk spreading that will occur. If an emptier does not turn up the implications to the home owner will be much smaller, compared to a situation where the latrine is only emptied when it's full. Research has looked at the issue surrounding time horizons regarding sanitation and the fact people do not save up, they just pay when it is time, so short time horizons are beneficial.

To work out a feasible emptying frequency a standard laboratory scale biogas experiment can be used on a sample from the area so a decay curve of biogas production can be plotted. The required production rate to meet demand will link to the samples age so the implementer will know the emptying frequency required. Refer to Wilkie et al (2003) for a more detailed method.

Conclusion
The feasibility of Biogas as a disposal solution has been analysed throughout this report by examining the technological, economic and social issues regarding its implementation, but it is clear to see the areas compliment each other. The research has highlighted a number of issues that any implementing organisation will have to face with a number of solutions proposed.

A combination of both shallower pits and permanent suction pipes (Figure) could be beneficial to solving fluidity/emptying issues and soiling up in pits (Figure), but also provide hygiene benefits to the emptier and fresher feedstock for the digester. The research suggests that haulage issues depend on time, not distance and therefore time benefit calculations would be required to ensure placement is economically feasible for the emptying contractor and customer. The critical factor when assessing digester placement is space, because without it there will be no other problems. Regarding pressure issues, the use of a storage vessel is proposed rather than just a comprehensive maintenance program because it provides the user with the ability to alter the pressure, however further assessment would be required.

Social and cultural constraints are very context specific; however, the importance of keeping the public fully informed for acceptability has been identified. Financial incentive is very powerful, therefore outlining the monetary benefit to program participants of increased emptying frequency will help smooth the change as well as ease social stigmas surrounding emptying contractors. Increasing the frequency of emptying has also been shown to decrease risk which is beneficial for both emptier and customer. The necessity of education programmes has been outlined with example tasks at each stage in Figure ; however, once again every programme will be context specific so a generic model would be hard to construct.

The addition of by-products provides a benefit to the FSM system which *closes the loop* and makes it more sustainable. The research has conveyed that by altering the flow of money the implementer can incentivise correct practice. However, research has highlighted the interaction between customer and emptying contractor to be weak, and therefore proposes to divert funds around this stage (Figure). A piloting scheme would be required to model the solution. Regarding management it is proposed that each stage in the process be the responsibility of an independent stakeholder but an overseeing organisation is provided to help regulate and manage transactions between parties. This way it promotes competition within each stage but retains the important element of teamwork.

Collaboration with a local water company is suggested as a solution for initial investment as well as its benefit as a management party in the organisational structure. The critical factor when assessing willingness to pay is making the use applicable to the community however, this must be done in conjunction with addressing acceptability of the gas. Again this is very context specific therefore collaboration with the community will be required.

Further reading

- *Biogas* Bates, L. (2007). Practical Action.
- *Pit Emptying Systems* Boot, N. (2007). Practical Action.
- *Talking Crap: Feacal Sludge Maqnagement in Accra, Ghana.* Boot, N. (2006). Loughborough: Loughborough University.
- *Excreta Disposal in Dar-es-Salaam*. Chaggu, E., Mashauri, D., Van Buuren, J., Sander, W., & Lettinga, G. (2002). *Environmental Management* , 609-620.
- *Simple Pit Latrine*. Chatterton, K. WEDC, Loughborough.
- *Bringing pit emptying out of the darkness: A comparison of approaches in Duran, South Africa and Bibera, Kenya.* Eales, K. (2005). Building partnershp for development in water and sanitation. http://www.bpdws.org/bpd/web/d/doc_131.pdf?statsHandlerDone=1
- *Small excreta disposal systems.* Faechem, R., & Cairncross, S. (1978). London: The ROSS Institute of Tropical Hygiene.
- The role of non-governmental organizations in decentralised wastewater management in Bangladesh. *WEDC International Conference* (pp. 86-90). Hasan, M., Uddin, N., & Parksinson, J. (2004).Vientiane, Lao: WEDC.
- Driving policy change for decentralised wastewater management (DWWM). *WEDC International Conference* (pp. 91-94). Heymans, C., McCluney, & Parksinson, J. (2004). Vientiane, Lao: WEDC.
- Review on the Integrated Use of Anaerobic Digestion in Developing Countires - Some Preliminary Findings. IRCWD. (1982, August). *IRCWD News* , pp. 9-11.
- *Biogas Digest Volume II Biogas - Application and Product Development.* Kossmann, W., Pönitz, U., Habermehl, S., Hoerz, T., Krämer, P., Klingler, B., et al. (1999).

Germany: Information and Advisory Service on Appropriate Technology.
- Biogas sanitation for black water or brown water, or excreta treatmentand reuse in developing countries. Mang, H.-P., & Li, Z. (2009). Eschborn, Germany: GTZ; sustainable sanitation – ecosan.
- Using a Biogas Digester. Colombo, Munasingha, S., & Wijesuriya, K. (2007).Sri Lanka: Practical Action.
- Implementation of Household Biogas Plant by NGO's in India. *VODO International Conference on Globilisation and Sustainable Development.* Antwerp: Myles, R. (2001). Belgian Government.
- Decentalized wastewater management in peri-urban areas in low-income countries. *Environment and Urbanization* , 75-90. Parkinson, J., & Tayler, K. (2003).
- *The Household Environmental Sanitation Approach*. Schertenleib, R., & Morel, A. (2003). Retrieved from http://www.sandec.ch/Publications/Publications/Home.htm
- *FS Management - Review of Practices, Problems and Initiatives.* Strauss, M., & Montangero, A. (2002). EAWAG/SANDEC.
- Sustainable Development Department. (1996). *A System Approach to Biogas Technology.* Food and Agriculture Organization of the United Nations.
- The United Nations. (1979). *Bioconversion of Organic Residues for Rural Communities*. Retrieved February 17, 2010, from http://www.unu.edu/unupress/unupbooks/80434e/80434E0k.htm
- *Guidance manual on water supply and sanitation programmes.* WELL. (1998). WEDC for DFID.
- *An economical bioreactor for evaluating biogas potential of particulate biomass.* Wilkie, A. C., Smith, P., & Bordeaux, F. (2003). Florida, USA: Elsevier Ltd.

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